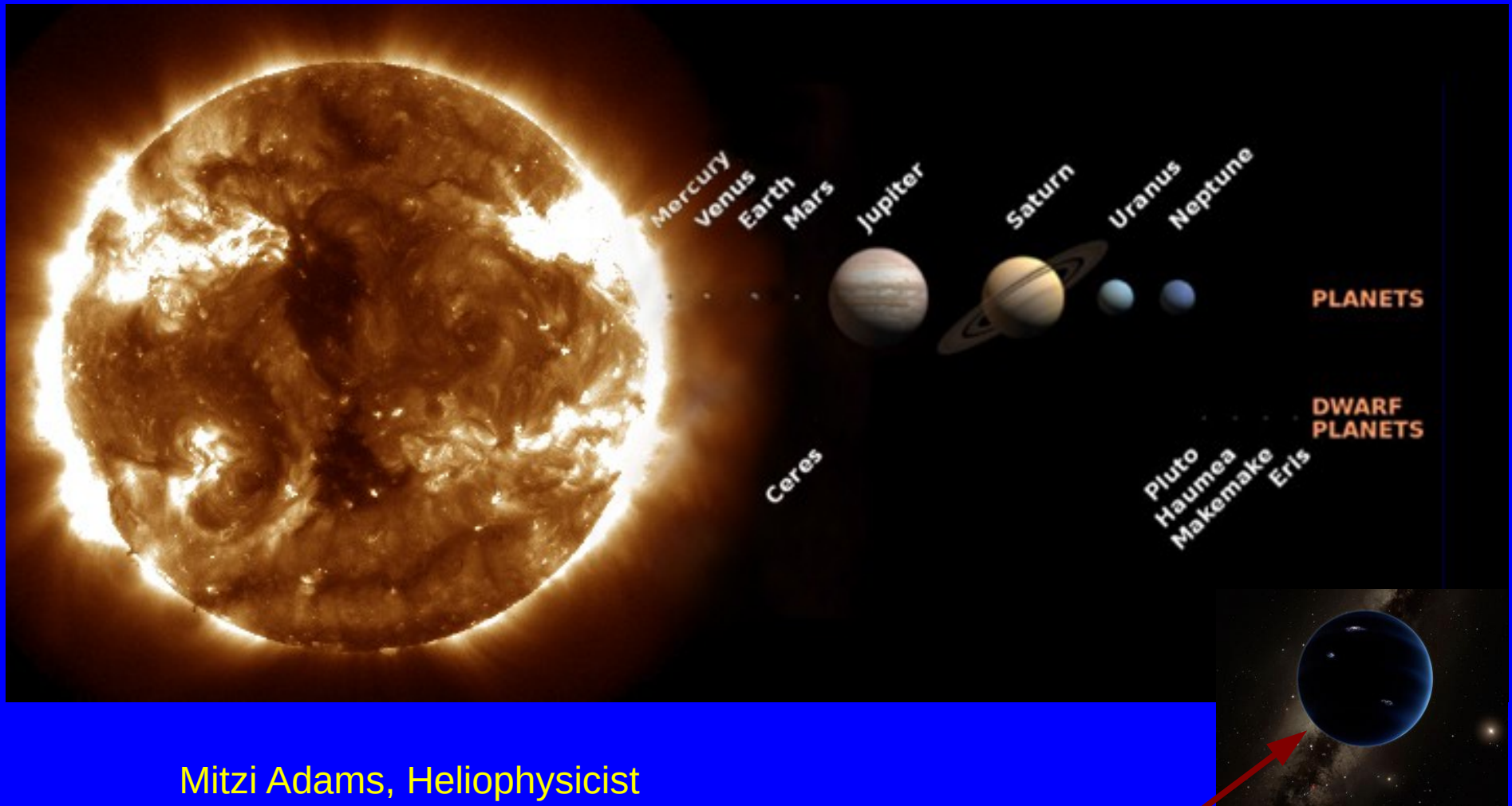


Our Dynamic Sun: A Star at the Center of the Solar System

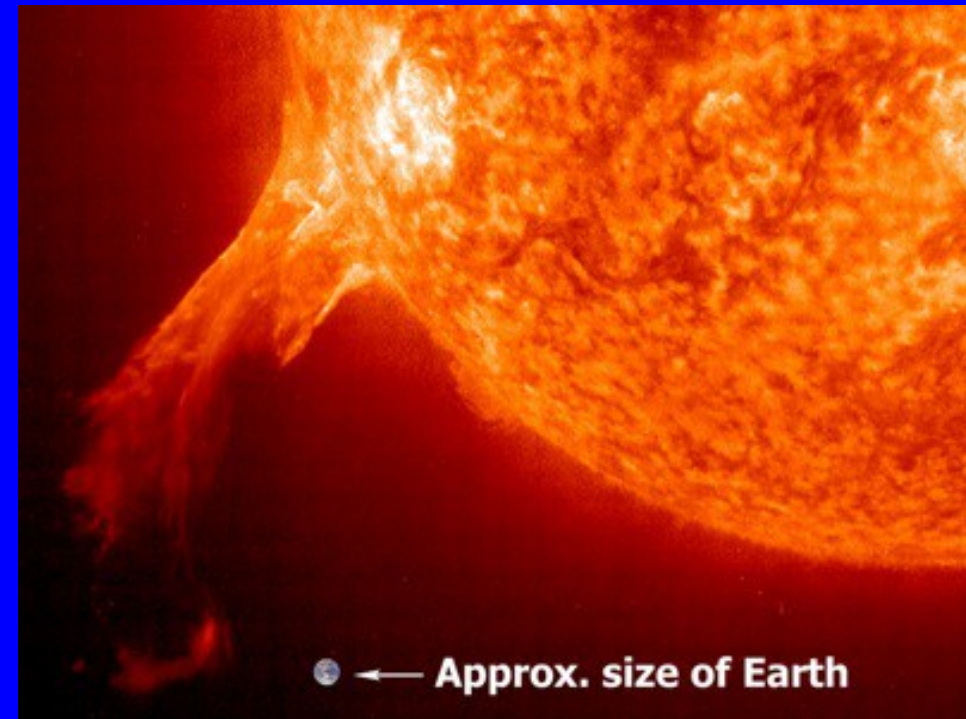
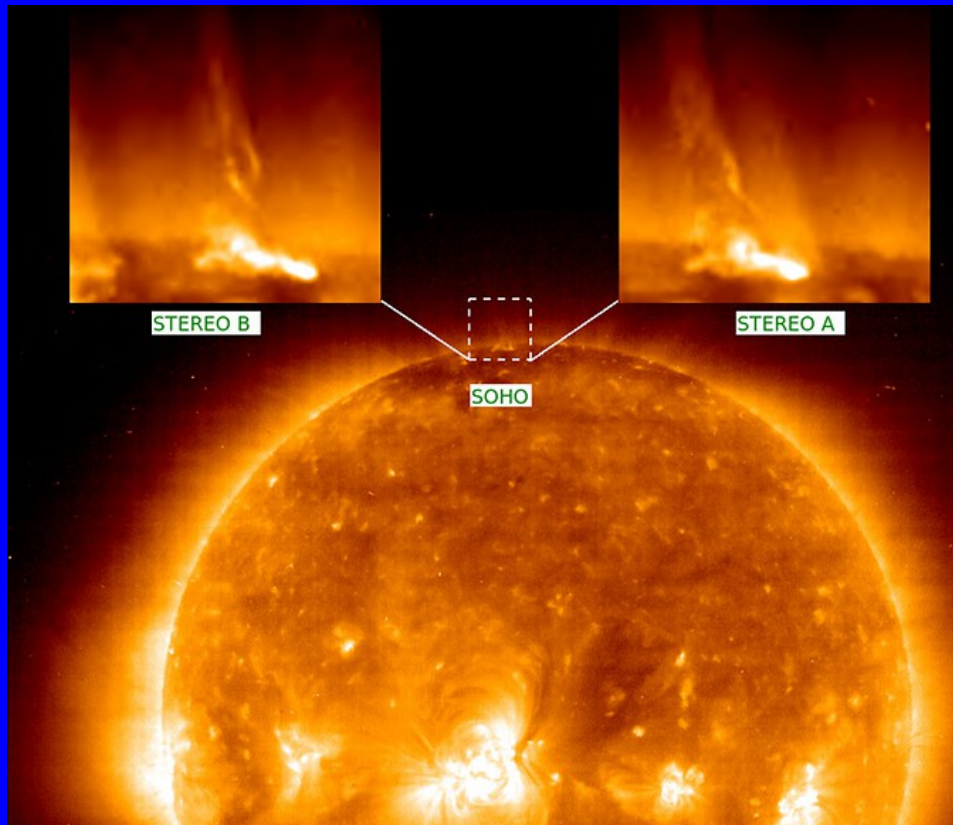


Mitzi Adams, Heliophysicist
NASA/MSFC

Presentation for the
University of Alabama in Tuscaloosa's
NASA Days
October 10, 2016

Planet
Nine?

There is a star at the center of our solar system!

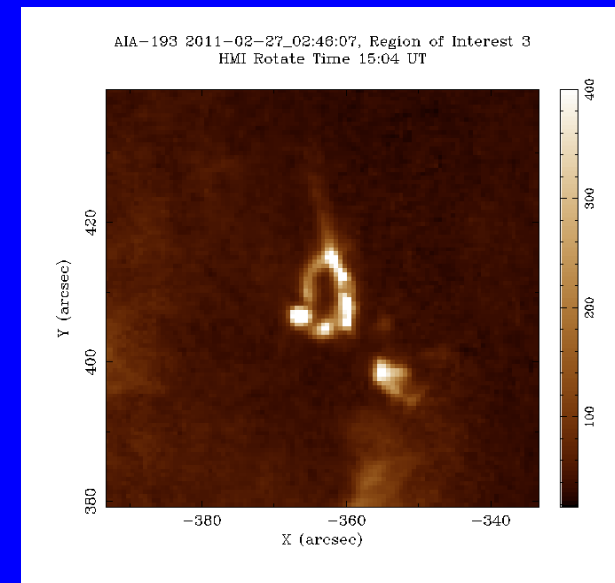


But what is a star?

How do stars work?

What are the characteristics of our Sun?

Are there impacts on Earth?



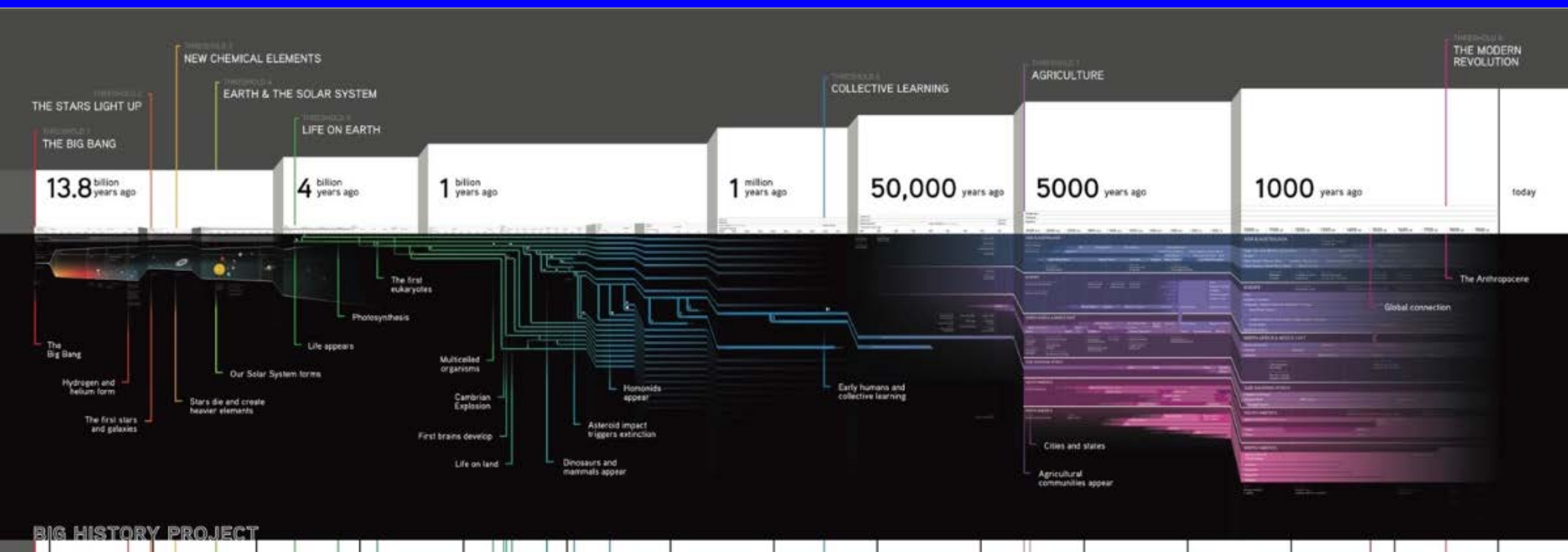
Who Am I ?

Mitzi Lynn Adams

- From Atlanta, Georgia where I was an observatory/planetarium assistant at Fernbank Science Center while in high school
- Earned a B.S. in physics with a mathematics minor from Georgia State University
- Earned a M.S. in physics from University of Alabama in Huntsville while in the co-op program with NASA/MSFC
- Worked as a solar scientist since 1988 in Huntsville
- As a volunteer, was planetarium director of the Von Braun Astronomical Society's planetarium from 1988-2006
- Like to run...have completed five marathons
- Like to visit Peru
- Like languages, meet with friends every Sunday to read Spanish and Latin and on Monday to read German



Putting it into Context *Astronomical* Scales



Time, Distance Size

How big is a million, a billion, 13.8 billion ?

Count numbers, consider each number as one second.

Count to one million -- 11.6 days

Count to one billion -- Multiply 11.6 days by 1000 = 32 years

Count to 13.8 billion --> 439 years

Perspective, continued...

The Sun is one of more than 100 billion stars in the Milky Way galaxy

There are over 30 galaxies in the local group with a diameter of ~10 million ly

The Sun is 25,000 light years from the galactic core

One galactic “year” takes about 250 million years.



Proxima Centauri: α -Cen-A and α -Cen-B are at about 4.37 ly away,
Proxima is 4.24 ly away

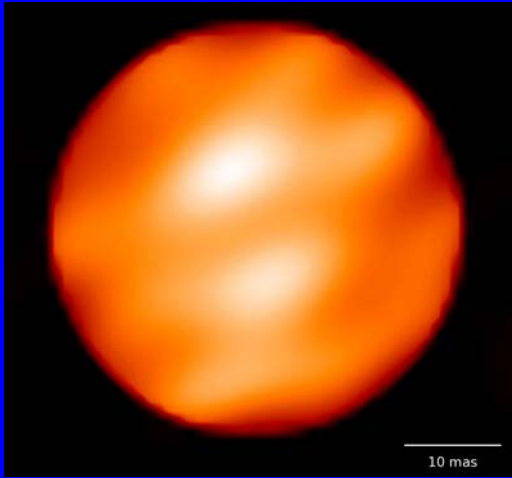
Imagine Sun to be grapefruit sized. With that scale, Alpha Centauri (the system) would be 4,000 kilometers or 2,500 miles away.

α -Cen-A is a G2, α -Cen-B is a K1, Proxima (α -Cen-C) is M6

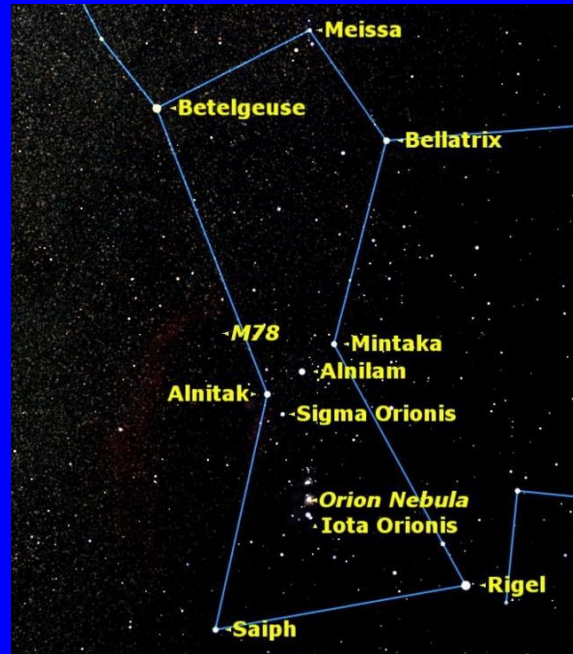
What is a Star?

What is a Star?

A star is an astrophysical body that produces its own light by thermonuclear reactions in its core.



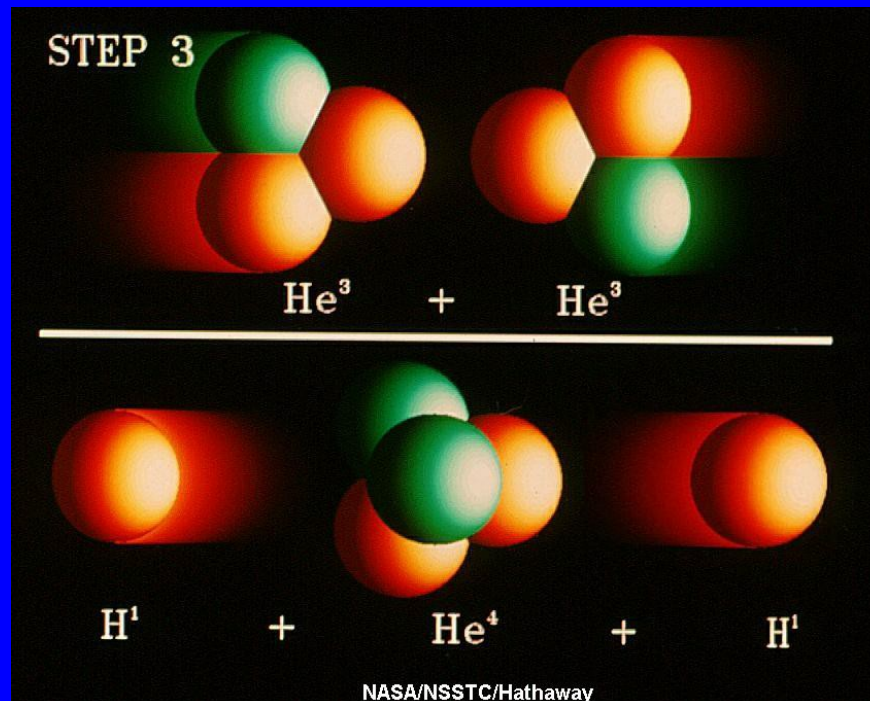
Betelgeuse: A red giant star, about 600 ly away, 3500 K, 1,180 R_{\odot} , 7.7 M_{\odot} .



Rigel: A blue-white star, about 770 ly away, 11,000 K, 80 R_{\odot} , 20 M_{\odot} .

Basically, hydrogen converts to Helium

(High-mass stars, greater than about 2 solar masses use a different procedure, called the CNO cycle.)



For sun-type stars, there are three steps in the proton-proton chain:

1. Two protons collide, form deuterium, a positron, and neutrino.
2. A proton collides with the deuterium, forming helium-3 and a gamma ray
3. Two He-3s collide to form He-4 plus two protons.

Layers of the Sun

The Convection Zone

Energy continues to move toward the surface through convection currents of heated and cooled gas in the convection zone.

The Corona

The ionized elements within the corona glow in the x-ray and extreme ultraviolet wavelengths. NASA instruments can image the Sun's corona at these higher energies since the photosphere is quite dim in these wavelengths.

The Radiative Zone

Energy moves slowly outward—taking more than 170,000 years to radiate through the layer of the Sun known as the radiative zone.

Sun's Core

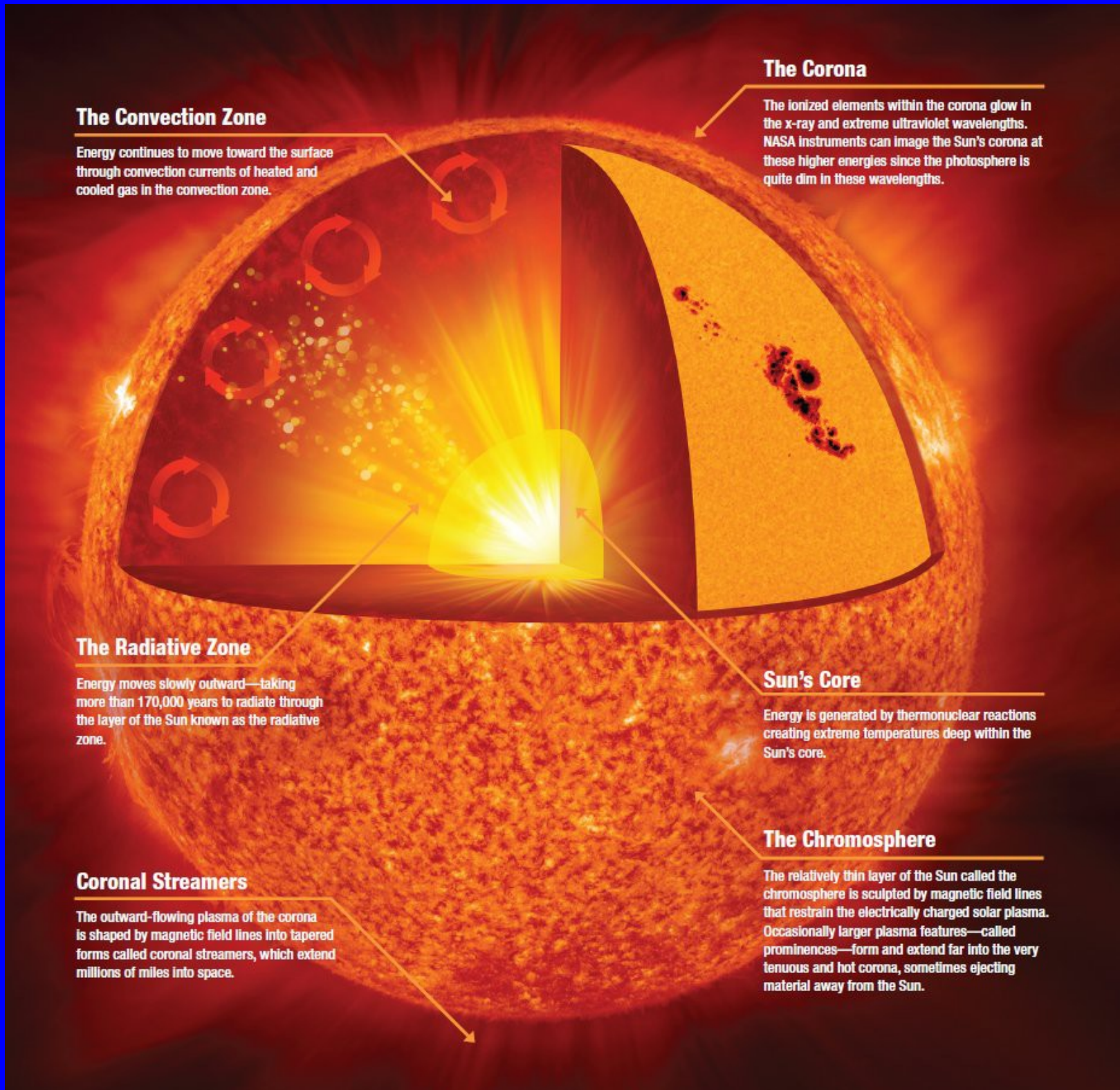
Energy is generated by thermonuclear reactions creating extreme temperatures deep within the Sun's core.

Coronal Streamers

The outward-flowing plasma of the corona is shaped by magnetic field lines into tapered forms called coronal streamers, which extend millions of miles into space.

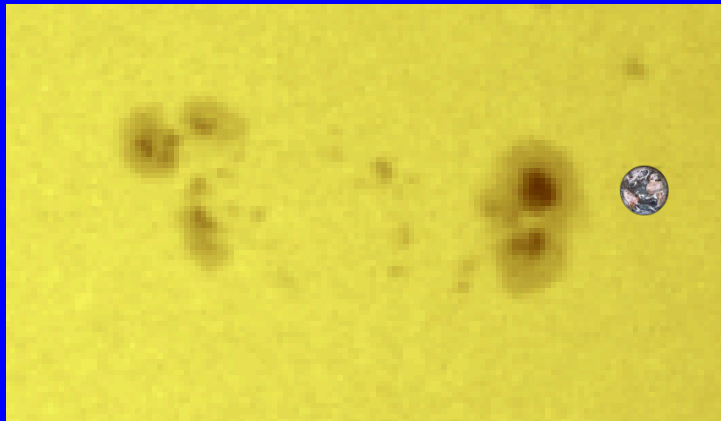
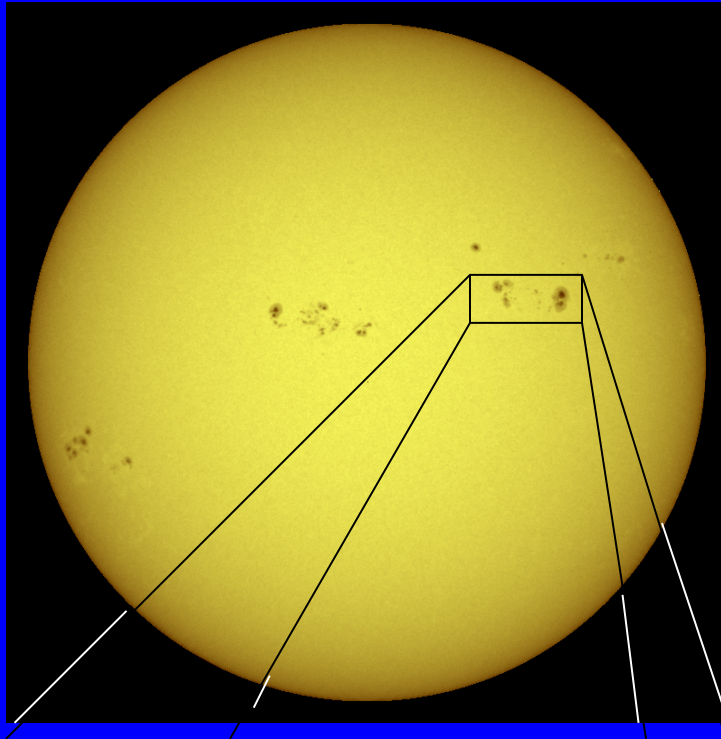
The Chromosphere

The relatively thin layer of the Sun called the chromosphere is sculpted by magnetic field lines that restrain the electrically charged solar plasma. Occasionally larger plasma features—called prominences—form and extend far into the very tenuous and hot corona, sometimes ejecting material away from the Sun.



Surface Features

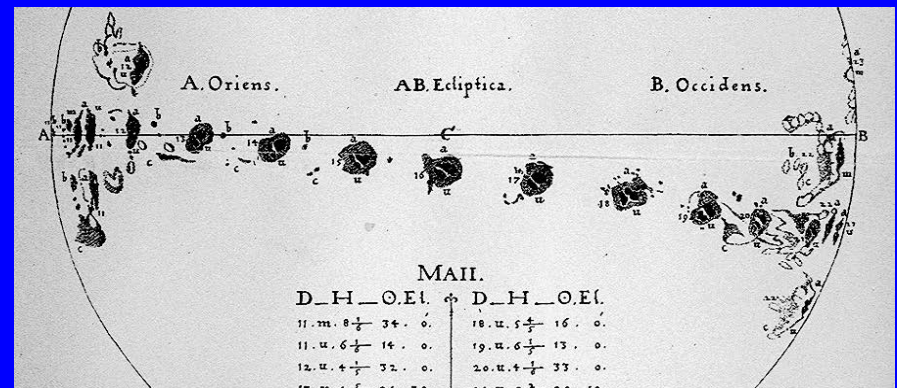
Sunspots



Sunspots are dark (and cooler) regions on the surface of the Sun. They have a darker inner region (the Umbra) surrounded by a lighter ring (the Penumbra).

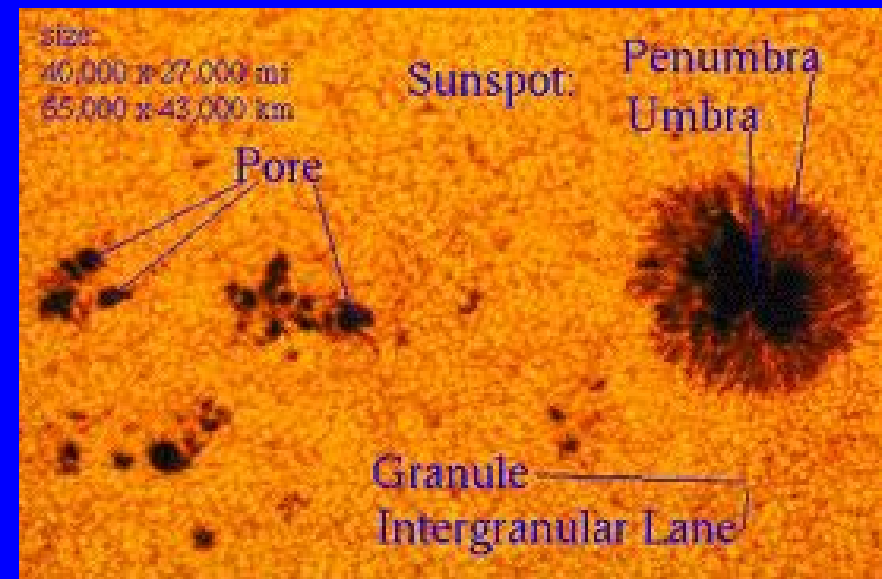
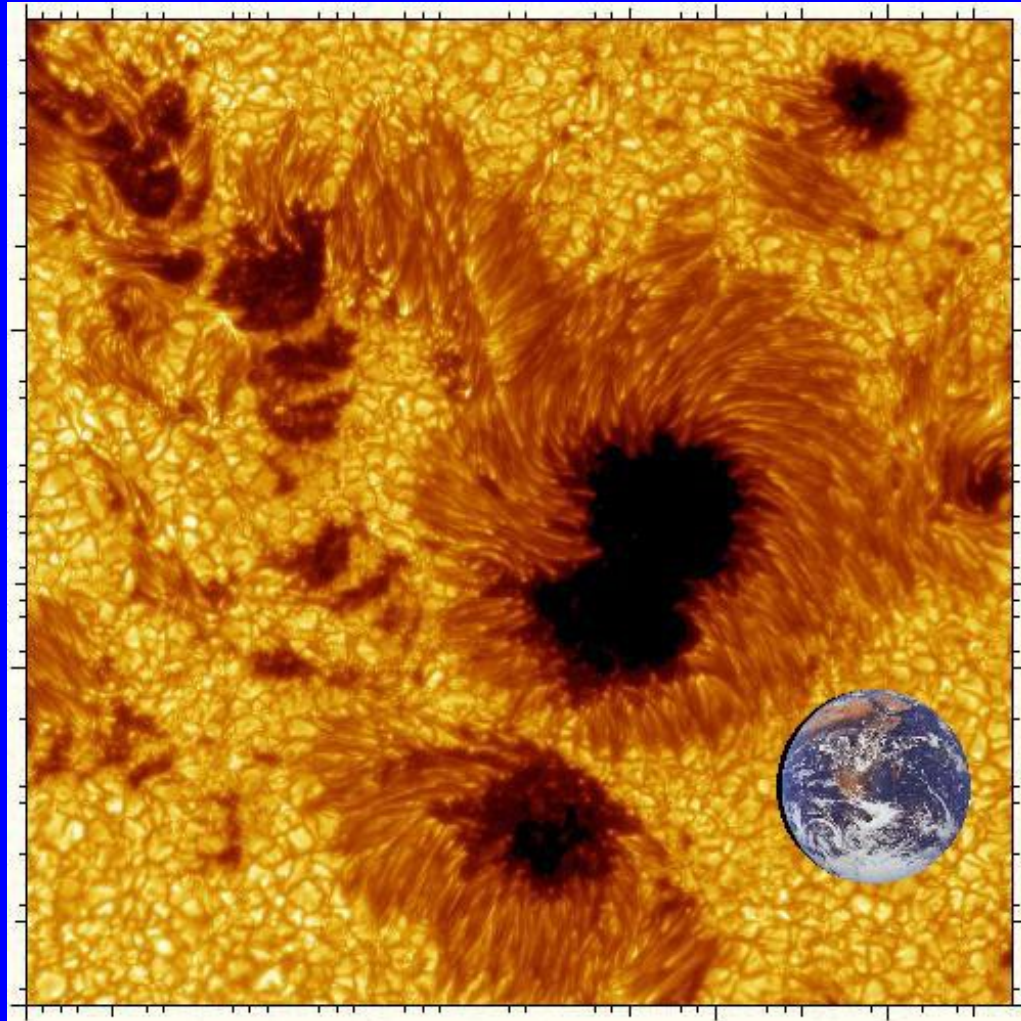
Sunspots usually appear in groups that form over hours or days and last for days or weeks.

The earliest sunspot observations (c. 1609) indicated that the Sun rotates once in about 27 days.



Sunspots

Examples

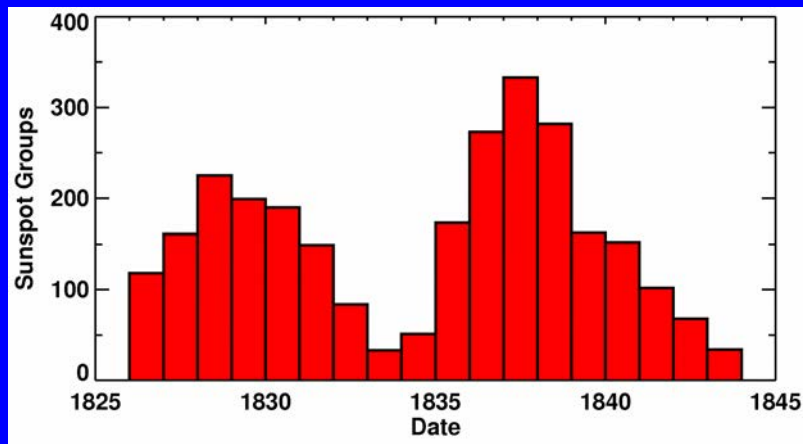


The Solar Cycle

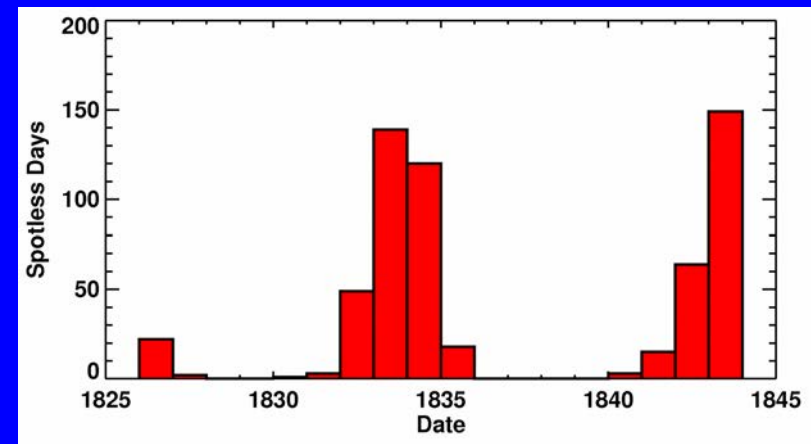
Sunspot Cycle Discovery

Astronomers had been observing sunspots for over 230 years before Heinrich Schwabe, an amateur astronomer in Dessau, Germany, discovered in 1844 that the number of sunspot groups and the number of days without sunspots increased and decreased in cycles of about 10-years.

Schwabe's data for 1826 to 1843

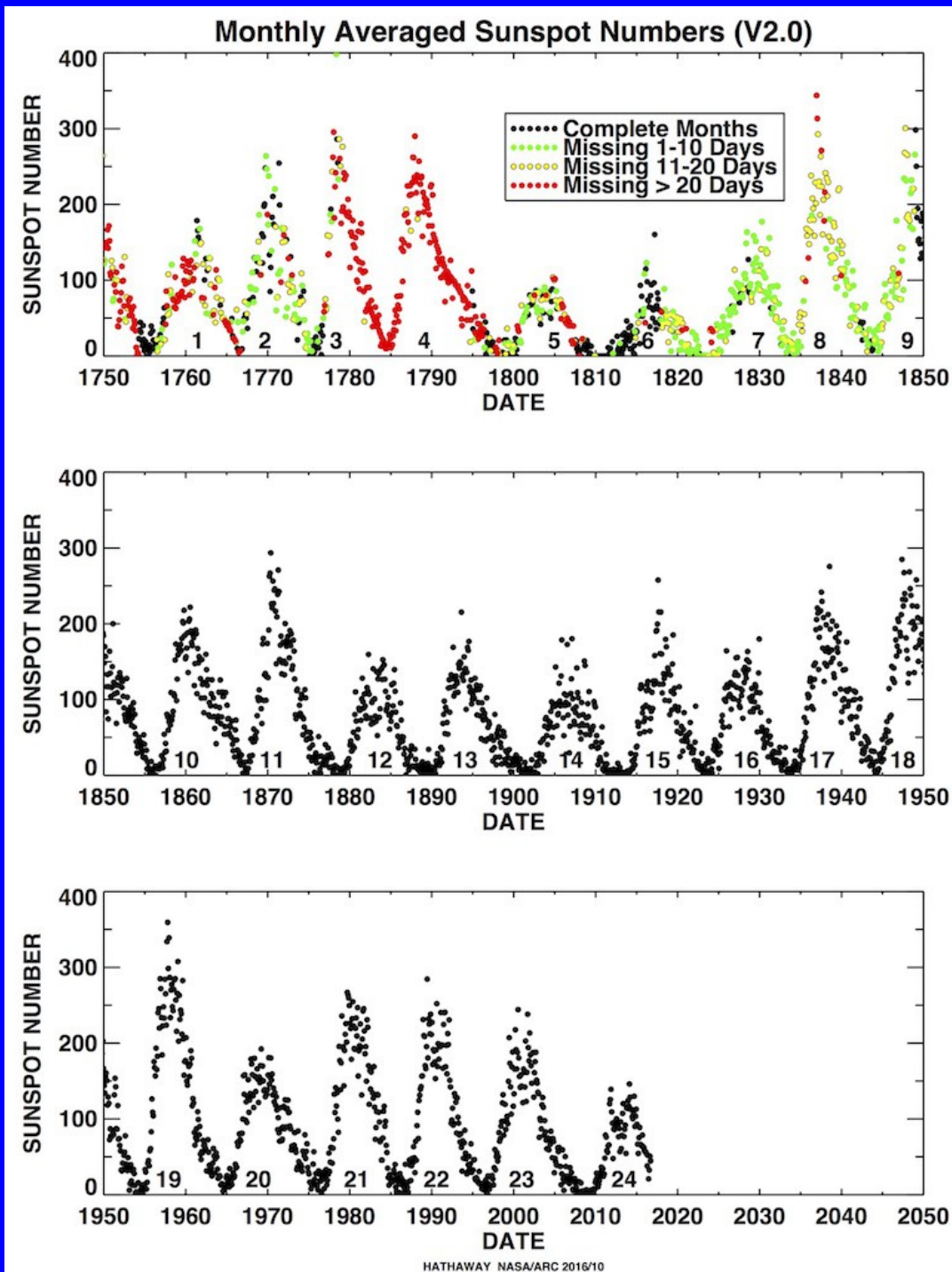


Number of Sunspot Groups per Year



Number of Spotless Days

23 Full Cycles



Shortly after Schawbe discovery Rudolf Wolf proposed using a “Relative” Sunspot Number count. While there were many days without observations prior to 1849, sunspots have been counted on every day since. To this day we continue to use Wolf’s Relative Sunspot Number and his cycle numbering.

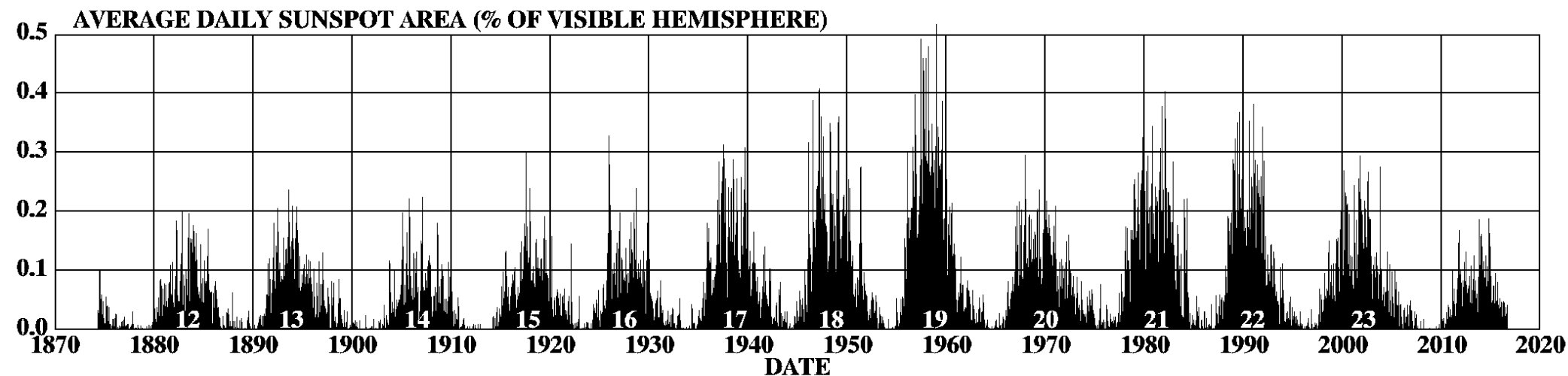
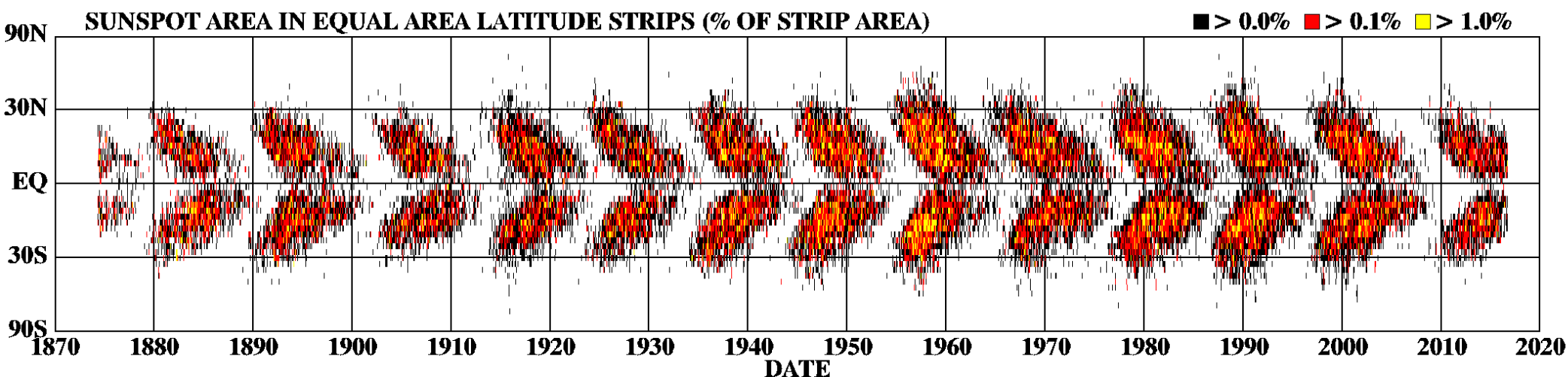
The average cycle lasts about 11 years, but with a range from 9 to 14.

The average amplitude is about 100, but with a range from 50 to 200.

Sunspot Latitudes

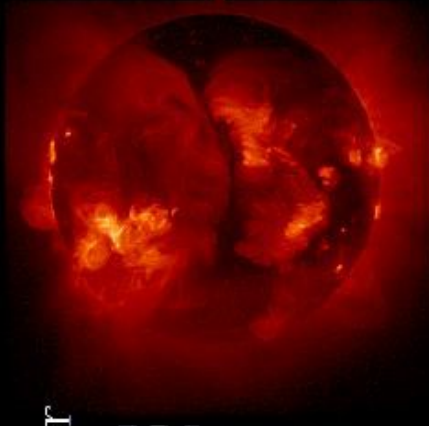
Sunspots appear in two bands on either side of the equator. These bands drift toward the equator as the cycle progresses. Big cycles have wider bands that extend to higher latitudes. Cycles overlap by 2-3 years.

DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS

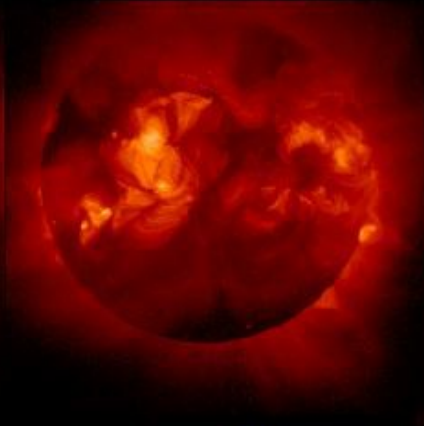


The Corona and the Solar Cycle

28 Sep 1991



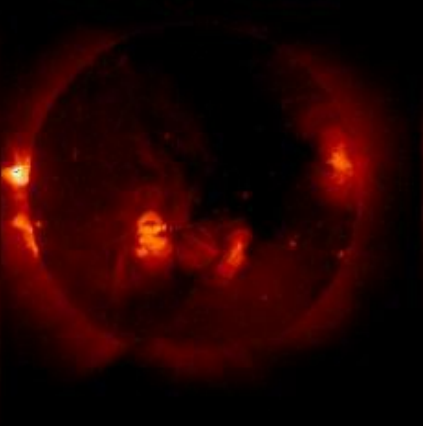
27 Mar 1992



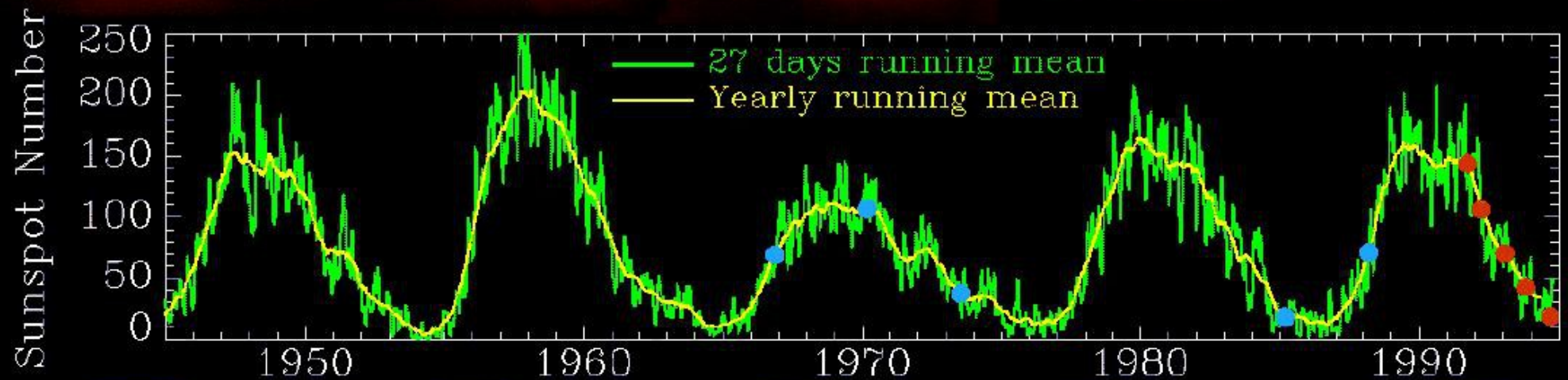
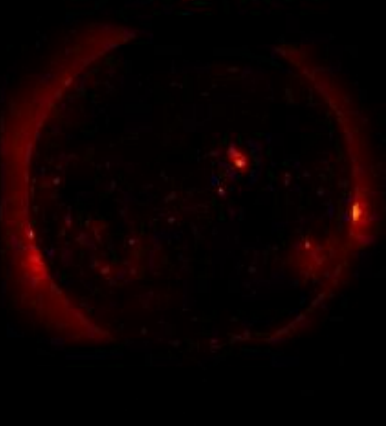
26 Jan 1993



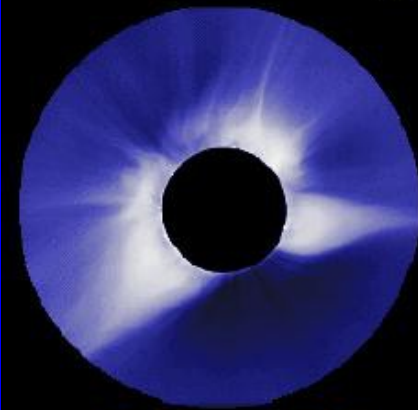
04 Nov 1993



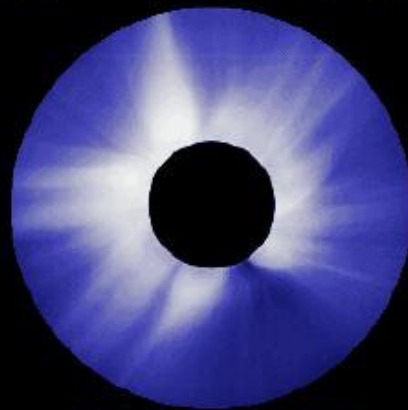
20 Sep 1994



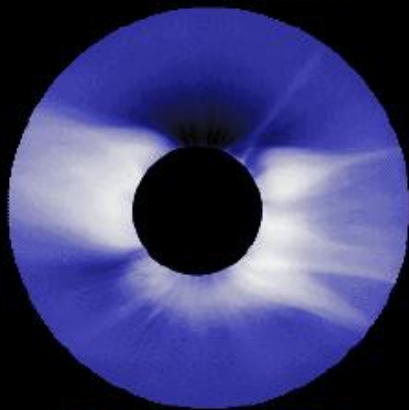
12 Nov 1966



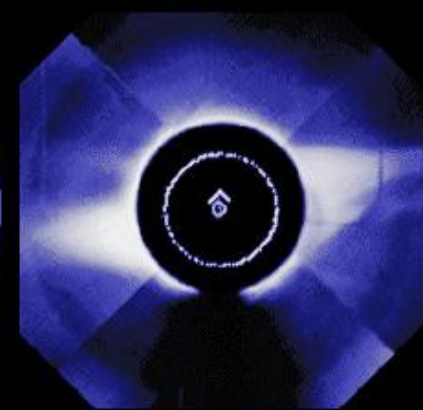
07 Mar 1970



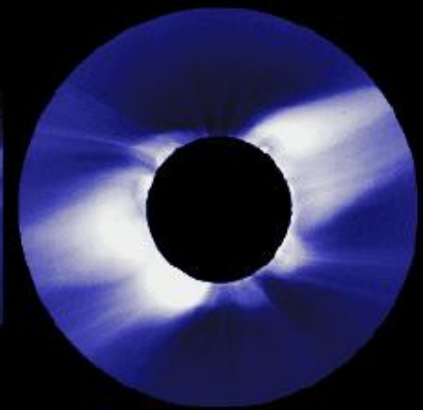
20 Jun 1973



11 Mar 1985

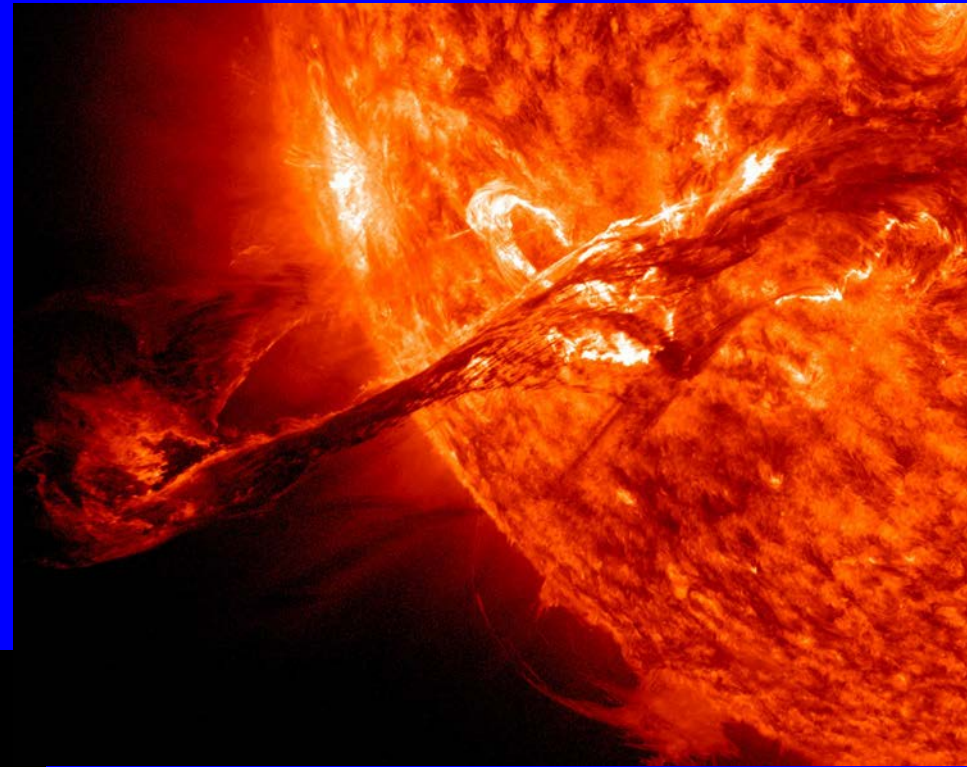
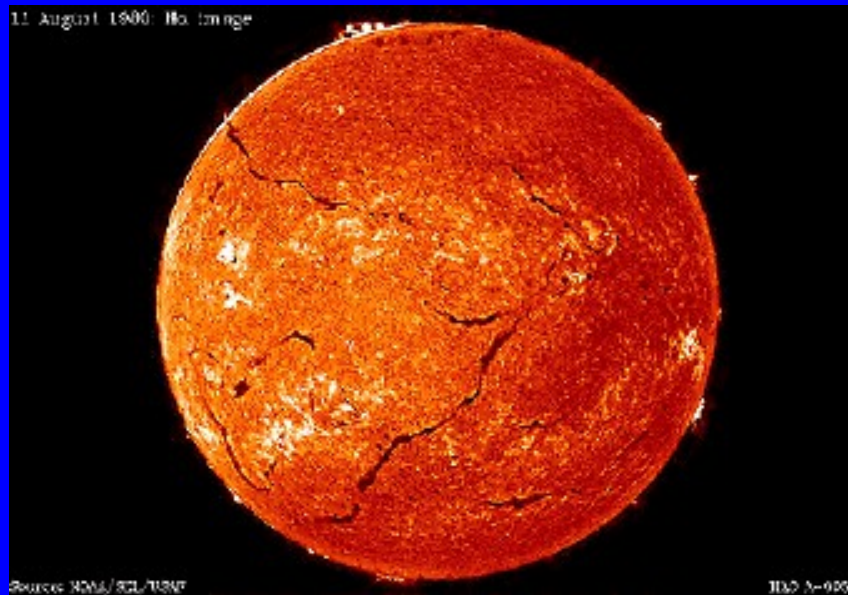


18 Mar 1988



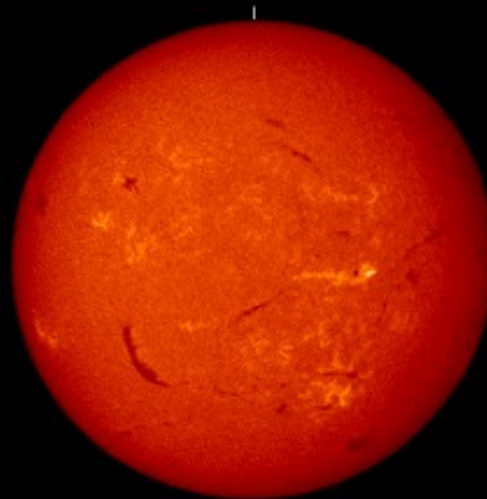
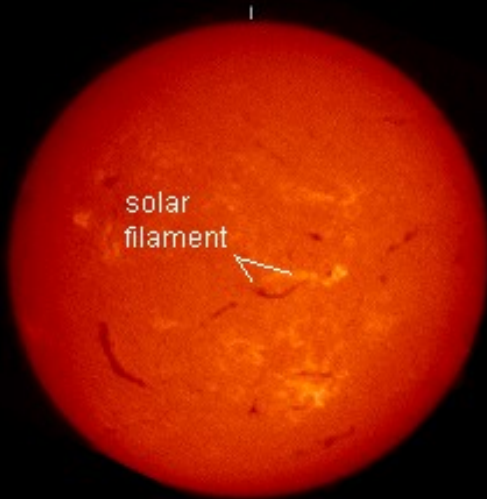
Solar Eruptions

Filament eruptions



BEFORE

AFTER



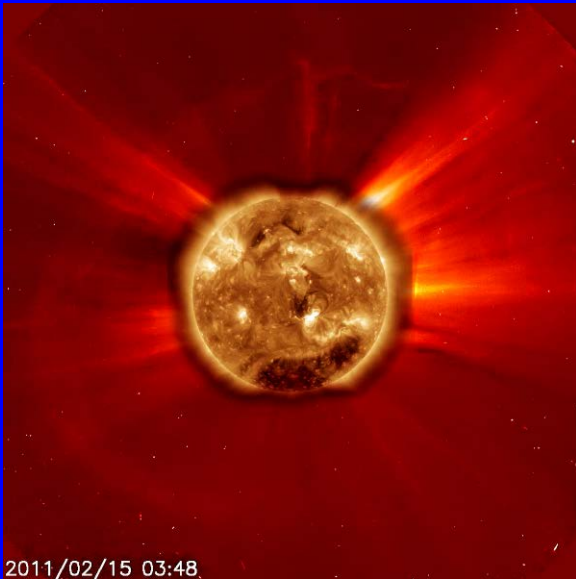
August 31, 2012, a filament erupted, triggering a CME. The plasma had speeds > 900 mi/s. This image is from SDO in 304 Å.

A filament around AR 9182 in October 2000. A C-7 flare was triggered, as well as a halo coronal-mass ejection (CME). Images from NOAA/SEC.

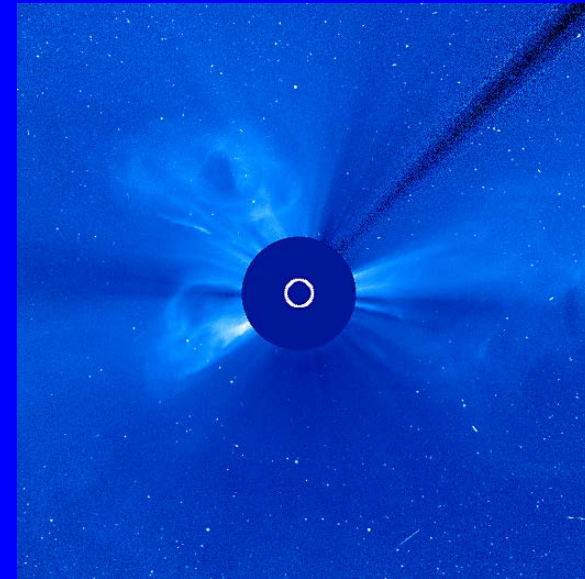
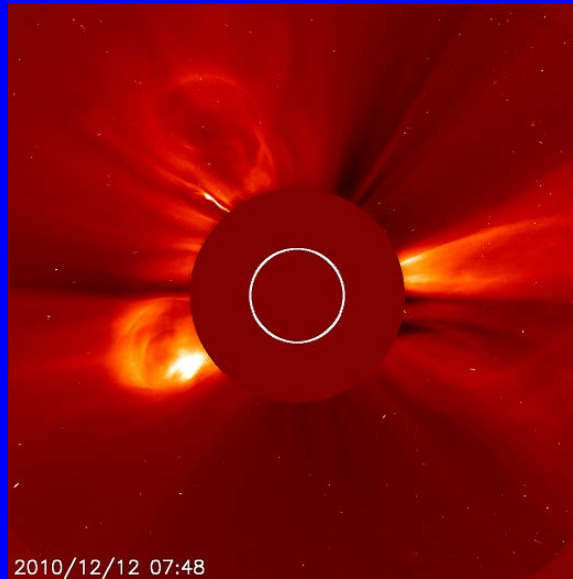
Movie!
Outburst304_big.mp4

Other Types of Solar Eruptions

Solar Flares and Coronal Mass Ejections (CMEs)



This combo of SDO and
Soho C2 shows X2-flare
and a halo CME

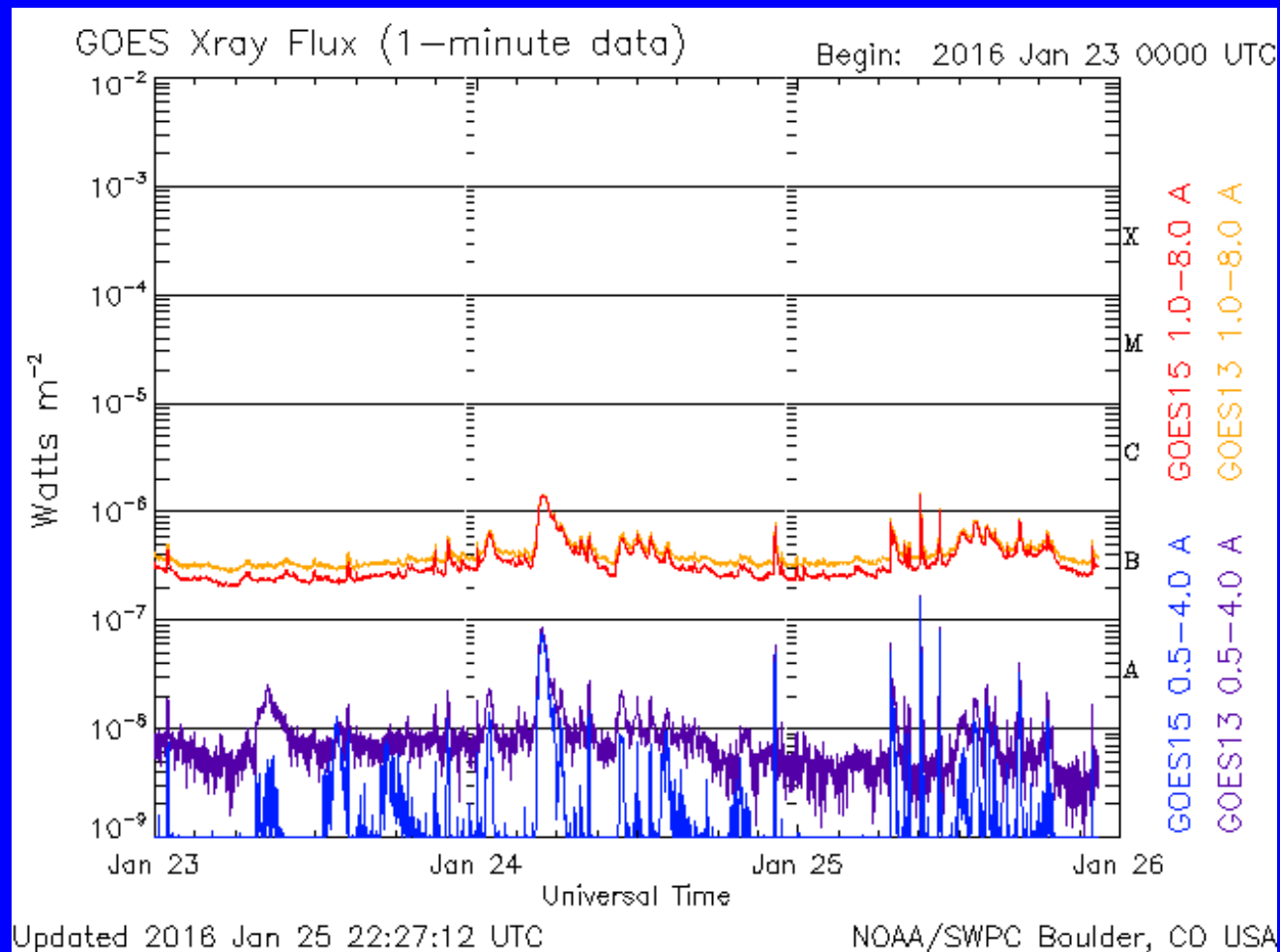


Three distinct CMEs: First (to right) was from a filament eruption, second from north pole, third from far side of Sun. All three eruptions happened within hours of each other.

Movies!

c2_halloween_2003.mpg, c3_halloween_2003.mpg, X2_C2_combo_best.mpg

How to Classify a Solar Flare



Solar Eruptions and Earth

Sunspots

Sunspots are comparatively cool areas at up to 7,700° F and show the location of strong magnetic fields protruding through what we would see as the Sun's surface. Large, complex sunspot groups are generally the source of significant space weather.

Coronal Mass Ejections (CMEs)

Large portions of the corona, or outer atmosphere of the Sun, can be explosively blown into space, sending billions of tons of plasma, or superheated gas, Earth's direction. These CMEs have their own magnetic field and can slam into and interact with Earth's magnetic field, resulting in geomagnetic storms. The fastest of these CMEs can reach Earth in under a day, with the slowest taking 4 or 5 days to reach Earth.

Solar Wind

The solar wind is a constant outflow of electrons and protons from the Sun, always present and buffeting Earth's magnetic field. The background solar wind flows at approximately one million miles per hour!

Solar Flares

Reconnection of the magnetic fields on the surface of the Sun drive the biggest explosions in our solar system. These solar flares release immense amounts of energy and result in electromagnetic emissions spanning the spectrum from gamma rays to radio waves. Traveling at the speed of light, these emissions make the 93 million mile trip to Earth in just 8 minutes.

Earth's Magnetic Field

Earth's magnetic field, largely like that of a bar magnet, gives the Earth some protection from the effects of the Sun. Earth's magnetic field is constantly compressed on the day side and stretched on the night side by the ever-present solar wind. During geomagnetic storms, the disturbances to Earth's magnetic field can become extreme. In addition to some buffering by the atmosphere, this field also offers some shielding from the charged particles of a radiation storm.

Space Weather

Space weather refers to the variable conditions on the Sun and in the space environment that can influence the performance and reliability of space-based and ground-based technological systems, as well as endanger life or health. Just like weather on Earth, space weather has its seasons, with solar activity rising and falling over an approximate 11 year cycle.

Sun's Magnetic Field

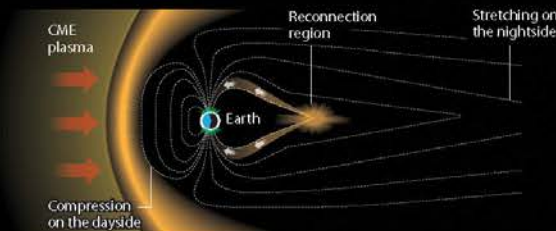
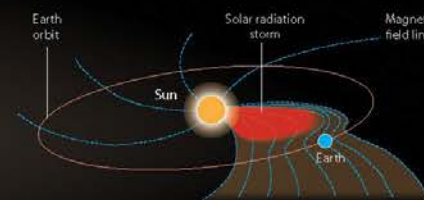
Strong and ever-changing magnetic fields drive the life of the Sun and underlie sunspots. These strong magnetic fields are the energy source for space weather and their twisting, shearing, and reconnection lead to solar flares.

Solar Radiation Storms

Charged particles, including electrons and protons, can be accelerated by coronal mass ejections and solar flares. These particles bounce and gyrate their way through space, roughly following the magnetic field lines and ultimately bombarding Earth from every direction. The fastest of these particles can affect Earth tens of minutes after a solar flare.

Geomagnetic Storms

A geomagnetic storm is a temporary disturbance of Earth's magnetic field typically associated with enhancements in the solar wind. These storms are created when the solar wind and its magnetic field interacts with Earth's magnetic field. The primary source of geomagnetic storms is CMEs which stretch the magnetosphere on the nightside causing it to release energy through magnetic reconnection. Disturbances in the ionosphere (a region of Earth's upper atmosphere) are usually associated with geomagnetic storms.



NOAA Space Weather Prediction Center - www.spaceweather.gov

Source images: NASA, NOAA

From an Executive Order Signed November 7, 2016 that specifies how the Federal Government will coordinate efforts to prepare the nation for space weather events: "Space weather means variations in the space environment between the Sun and Earth (and throughout the solar system) that can affect technologies in space and on Earth. The primary types of space weather events are solar flares, solar energetic particles, and geomagnetic disturbances."

Aurorae

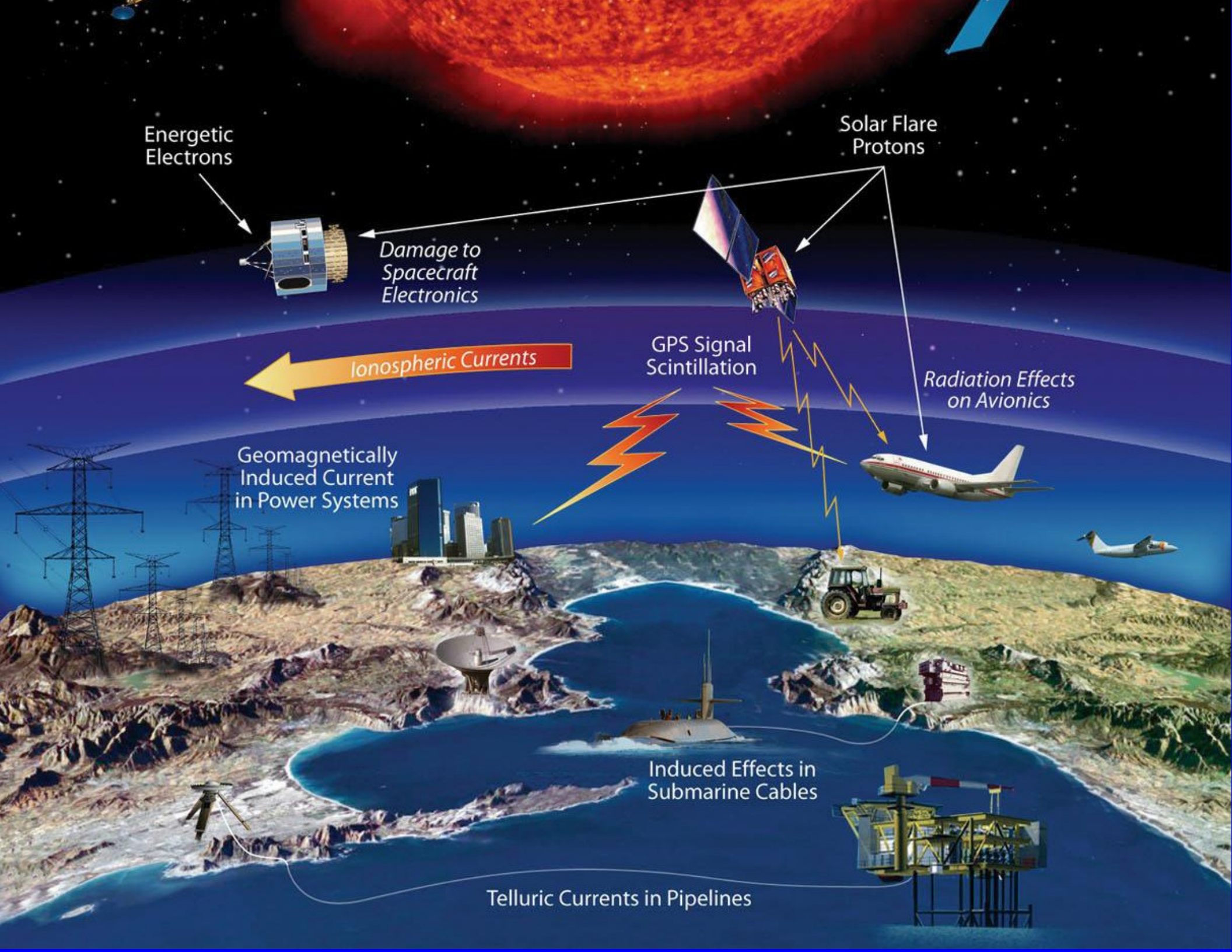


Seen mostly at high latitudes, aurorae are produced when Earth's magnetosphere is disturbed.

Plasma from the magnetosphere precipitates into the upper atmosphere.

Reds are from oxygen (630 nm)
Greens at 557.7 nm are from lower in atmosphere.





Energetic
Electrons

Solar Flare
Protons

Damage to
Spacecraft
Electronics

Ionospheric Currents

GPS Signal
Scintillation

Radiation Effects
on Avionics

Geomagnetically
Induced Current
in Power Systems

Induced Effects in
Submarine Cables

Telluric Currents in Pipelines

Summary

Our Sun is a single star with a system of planets

The Sun is a stable star, currently happily converting hydrogen to helium

The Sun will remain on the Main Sequence of ~ 4.5 billion years more

The Sun is an active star, which produces spots, flares, and coronal mass ejections

Solar eruptive phenomena can create problems for our technological society such as power outages, computer upsets, orbital decay of satellites, radio blackouts, pipeline degradation

Eclipse Across America

August 21, 2017

National Aeronautics and
Space Administration



What is a Solar Eclipse?

A **solar eclipse** happens when the Moon, as it orbits Earth, fully or partially blocks the light of the Sun, thus casting its shadow on Earth.

Observers within the path of totality can expect to see something like the image below. Observers outside the path of totality will see the Sun partially eclipsed as a crescent Sun (with safe filters).

Greatest Eclipse

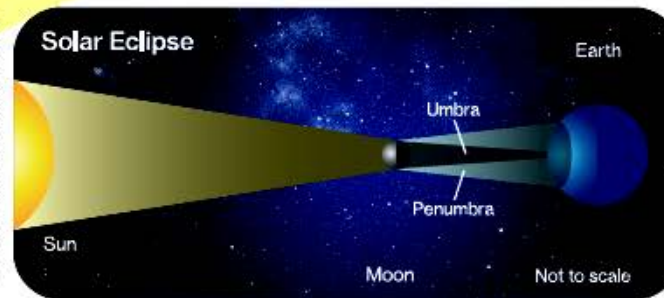
Time	Location
10:17 a.m. PDT	Lincoln Beach, OR Depoe Bay, OR
11:26 a.m. MDT	Lime, ID
1:19 p.m. CDT	Valley View, MO Bloomsdale, MO
1:28 p.m. CDT	Callistia, TN
2:47 p.m. EDT	Bethera, SC

After the 2017 solar eclipse, the next **total solar eclipse** visible over the continental United States will be on **April 8, 2024**.

If the Sun is scaled to about 10 cm (3.9 in), Earth would be about 10 meters away (33 feet).



©1999 by F. Espenak, MrEclipse.com



©1999 by F. Espenak, MrEclipse.com

The predicted path of the August 21, 2017 solar eclipse

Duration of Greatest Eclipse:

2 min 40 sec

(18:25 UT=13:25 CDT or 1:25 p.m. CDT)

Location Greatest Eclipse:

36 deg 58 min N; 87 deg 40 min W
(between Princeton and Hopkinsville, KY)

Path Width: **approximately 115 km**

Eclipse Predictions by Fred Espenak, GSFC, NASA-emeritus



Never look directly at the Sun unless you have filters that you know are safe.

For more information:

For more information about solar eclipses:

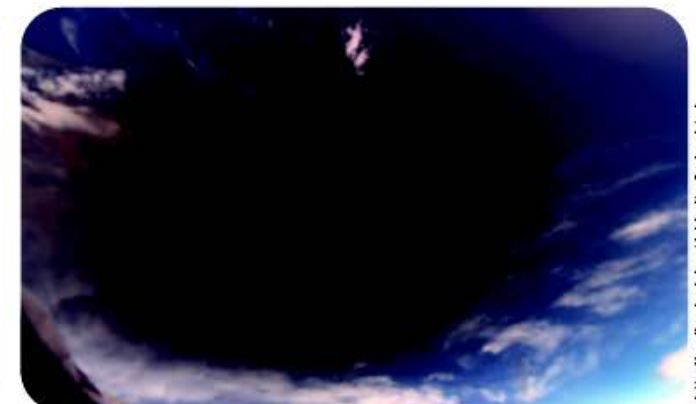
<http://eclipse.gsfc.nasa.gov/SEhelp/safety.html>

<http://eclipse.gsfc.nasa.gov/solar.html>

<http://eclipsewise.com/solar>

<http://eclipsewise.com/solar/SEnews/TSE2017/TSE2017.html>

<http://eclipse2017.nasa.gov/>



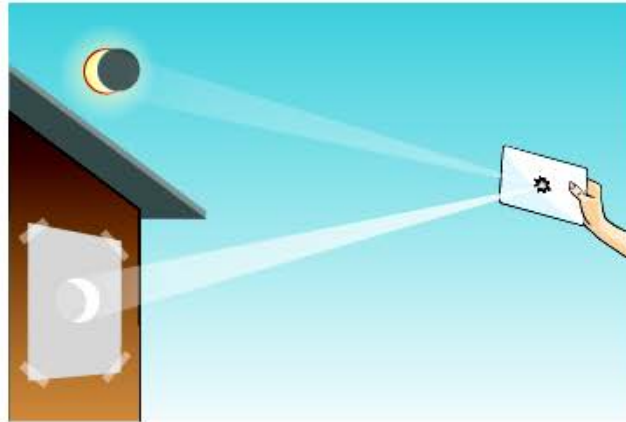
<http://mail.colonial.net/~hkaiter/index.html>

The NASA image above shows the Moon's umbral shadow as seen from the International Space Station during the total solar eclipse on 29 March 2006.

Mitzi Adams • mitzi.adams@nasa.gov • 256-961-7626

Safely Observing the Sun

WARNING: Never look directly at the Sun without proper eye protection. You can *seriously* injure your eyes.



Mirror in an Envelope
Slide a mirror into an envelope with a ragged hole cut into the front. Point the mirror toward the Sun so that an image is reflected onto a screen at least 5 meters (about 15 feet) away. The longer the distance, the larger the image.

Do not look at the mirror, only at the screen.

Photograph (below) Copyright © Elisa J. Israel



Strange Shadows!

Sunlight through trees produces projected crescents during partial phases.

Go Stick Your Head in a Box

You can make this simple "eclipse telescope" with some cardboard, paper, tape, and foil.

The longer the distance from the pinhole to screen, the larger the image of the Sun will be

White paper screen taped to inside end of box

Small image of partially eclipsed Sun



Sunlight

Aluminum foil with pinhole



Sun Funnel

Make this device for your telescope with simple instructions at: www.astrosociety.org/toy/Build_a_Sun_Funnel.pdf

Cool in the Shades

Visit the Von Braun Astronomical Society (or your local astronomical society) and pick up a pair of these special Eclipse Sunglasses!

www.vbas.org

The Great American Eclipse
August 21, 2017



Von Braun
Astronomical
Society

www.vbas.org



All images used with permission.

Local Area Eclipse Details

Location	% Covered	Start (CDT)	Max (CDT)	End (CDT)
Nashville, TN	100.0%	11:58AM	1:28PM	2:54PM
Totality begins 1:27PM • Totality ends 1:29PM				
Brentwood, TN	100.0%	11:58AM	1:28PM	2:54PM
Totality begins 1:28PM • Totality ends 1:29PM				
Franklin, TN	99.9	11:58AM	1:28PM	2:54PM
Fayetteville, TN	98.2	11:59	1:30	2:56
Ardmore, AL/TN	97.3	11:59	1:29	2:55
Florence, AL	95.9	11:57	1:28	2:54
Athens, AL	96.7	11:59	1:29	2:56
Decatur, AL	96.1	11:59	1:30	2:56
Hartselle, AL	95.8	11:59	1:30	2:56
Madison, AL	96.7	11:59	1:30	2:56
USSRC	96.8	11:59	1:30	2:56
Huntsville, AL	97.0	11:59	1:30	2:56
VBAS	97.1	12:00NOON	1:30	2:56
Arab, AL	96.0	12:00	1:31	2:57
Gurley, AL	97.1	12:00	1:31	2:57
Guntersville, AL	96.4	12:01	1:31	2:57
Scottsboro, AL	97.4	12:01	1:31	2:57
Bridgeport, AL	98.6	12:01	1:32	2:57

JAVA Script Solar Eclipse Explorer
<http://eclipse.gsfc.nasa.gov/JSEX/JSEX-NA.html>